The Lost-Wax Casting of Icons, Utensils, Bells, and Other Items in South India

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Indian artisans and craftsmen have long been masters at extracting and shaping metals and alloys, as proven by archaeological finds from the 2nd–3rd millennia B.C. For example, two well-known artifacts, castings of the dancing girl of Mohenjo Daro and the Mother Goddess of Adichanallur, Tamilnadu, depict a high degree of metallurgical knowledge. Those castings were formed by the lost wax process, which later was modified and became known as investment casting. In various parts of India, this age-old casting process is still being practiced, without any major modifications. This paper discusses details of the process used by the Indian artisans of Swamimalai, Tamilnadu, and Mannar, Kerala, South India in shaping copper-base alloys into icons and utensils, bells, and lamps.

INTRODUCTION

The history of metals and their shaping is as ancient as the history of civilization. Mastery of the mining, extraction, and working of metals was instrumental in the growth of the material culture. Many artifacts that have been excavated and preserved, as well as some of the metallurgical arts still being practiced, are examples of advanced, yet ancient, metallurgical skills. Historically, the Indian subcontinent was on par with the rest of the world in its metallurgical skill and expertise, and its artisans and craftsmen were masters at extracting and shaping metals. In fact, Indian knowledge of metallurgy predates technologies of many other civilizations, as shown by archaeological finds from the 2nd and 3rd millennia B.C.

Numerous ancient metallurgical arts and artifacts provide evidence of Indian excellence in the shaping of ferrous and nonferrous metals and alloys, including:

- The dancing girl of Mohenjo Daro, the earliest known Indian lost wax process cast bronze figure (3rd millennium B.C.).
- The bronze icon of Lord Nataraja (8–15th century A.D.) and the 3,000 year old bronze figure of Mother Goddess discovered at Adichanallur, Tamilnadu, South India; both were cast by the lost wax process.
- Dhokra ware of central and eastern India, for which the lost wax process was used to craft bells and other brass items.
- The iron pillar, Qutab Minar, in New Delhi (310 A.D.), which demonstrated forge-welded, excellent quality wrought iron.

- The Aranmula metal mirror, an example of using a very slow cooling rate to precipitate hard and brittle intermetallics in high-tin bronze (16th century).
- A bowl and gong, providing excellent examples of thermomechanical processing of difficult-to-shape high-tin bronze (16th century).
- Wootz or Damascus steel (2nd century A.D.), exemplifying advanced techniques for melting, shaping, and treating of steel.
- Guns and cannons, examples of forging technology in the absence of iron-casting technology.
- The iron craft of Bastar, in which icons and votive animals were made from pure iron.

In addition to these artifacts, during the reign of Alexander the Great, swords manufactured in the Middle East and Europe were made of steel imported from India. These metallurgical works were evidence of a high degree of technical excellence in shaping metals and alloys in general and copper-base alloys in particular as a single system.

Bronzes are copper-tin alloys. Those containing more than 11% tin have no engineering applications because of their increasing brittleness and, hence, decreasing ductility.[12] However, high-tin bronzes containing 20–30% tin, also known as ß bronze or speculum or bell metal, have long been shaped and utilized as consumer articles such as mirrors, kitchen wares, musical instruments, bells, and ornaments in many parts of the world, including India.[1-14] The peculiar properties of high-tin bronze—hard and brittle on slow cooling, ductile and malleable when worked at a particular temperature range, inert to the food native to Kerala (a southern province of India), and sonorous after hot working and quenching—had been identified and exploited by the Kerala artisans for shaping this material into metal mirrors ("aranmula kannadi" in Malayalam language),[7-11] eating bowls ("Kadavaloor ottu kinnam" in Malayalam),[9-13] and gongs ("kathakali chengala" in Malayalam).[9-11] Because the lost-wax process is still being used by the traditional metal workers in some areas of India, these metallurgical arts can be studied to gain insight into the science behind them. This article will review the authors' studies of shaping bronze and other suitable copper-base alloys into icons, bells, lamps, etc. by the lost-wax technique in Swamimalai (Tamilnadu) and Mannar (Kerala), South India.

ICON MAKING AT SWAMIMALAI, TAMILNADU

August Rodin, the famous sculptor, described the bronze icons of South India as "the most perfect representation of rhythmic movement in art."[12] These icons were and are still cast by Cire Perdue (cire and perdue meaning wax and lost, respectively). The

lost-wax process[11,14,15] became known as investment casting after a thorough modification and is now used for casting gas turbine blades, biomedical implants, etc. Lost wax has been the name used for all types of casting wherein a wax model forming the core of the image is drained out, then replaced by metal in the actual casting. This replacement can take place by two processes—solid casting ("ghana" in Sanskrit) and hollow casting ("sushira" in Sanskrit), both of which are referenced in the Rig Veda. Solid casting is still prevalent in South India (Swamimalai, Tiruchirapalli, Madurai, Chengleput, and Salem in Tamilnadu; Bangalore and Mysore in Karnataka; Mannar, Irinjalakuda in Kerala; and Tirupathi in Andhra), while the latter is largely prevalent in Central and Eastern India. The Silpasastra, an ancient Sanskrit text on icon making and the most elaborate treatise on the process believed to be compiled during Gupta period, set forth the composition and the preparation of the different alloys to be used, the measurements and the relative proportions of the different parts of icons, the method of preparing the wax model, and the making of the mold and the casting.

The unit of measurement in icon making is tala, which is the distance between the hairline and the end of the lower jaw. The tala is divided into 12 equal parts called angulas (equivalent to the breadth of a finger). Each angula is divided into eight yava (the size of a barley grain) and so on until the smallest unit, a paramu (smaller than the end of a single hair). The craftsmen use traditional tools, most of which are made by them. Of late, electrically operated tools such as drills, blowers, and files have been used. Icon making consists of the following four major steps:

- Pattern/Model making: Pattern rule (Odiolai in the Tamil language) making, preparation of wax, and wax model making (Figure 1).
- Mold making: Mold making by investing (Figures 2 and 3), and melting and draining of wax from the mold cavity.
- Melting and casting: Preparation of alloy and casting.
- Fettling and finishing: Mold opening; finishing, engraving, and polishing; and coloring.

Figure 1. A completed individual wax pattern/model of the child Krishna and a banyan tree leaf.

Figure 2. Completed mold halves with patterns after sun drying readied them for initiating preparation of other mold halves.

Figure 3. Completed molds for an icon of the child Krishna and banyan tree leaf.

Initially, the artisan takes note of the proportion and measurements (i.e., talas) as laid down in Silpasastras for icon making and makes a pattern rule, which is a narrow ribbon of coconut tree leaf cut to the icon length requirement and folded at different lengths in proportion to the length of various parts of the icon. This means that the artisans make an individual pattern rule for a given size and shape of an icon.

Wax required for making the model or pattern of the icon is prepared by mixing pure bee's wax, resin from the tree Damara Orientalis, and ground nut oil in the ratio 4:4:1. The powdered resin is mixed with ground nut oil and the mix is heated until a thick liquid forms. Next, bee's wax is added to the thick liquid and stirred until it liquefies and gets well mixed. This wax melt is strained through a fine metal sieve or coarse-woven cloth into a container of cold water, thus allowing it to solidify. The wax mix is then used for wax model making.

Wax model making is a crucial step wherein the craftsman's creativity decides the excellence of the model, and, in turn, of the icon to be cast. The head, body, and limbs of an icon are made separately by hand, using the wax mix after making it malleable by warming it and later shaping it using spatula, knife, and scraper. The finished parts of the icon are joined by using a hot iron tool as a soldering iron to melt their joining surfaces. The model or pattern for the icon's pedestal is made as an integral part of the icon if the icon is small, or individually if the icon is large. To strengthen the wax pattern as well as to facilitate the flow of molten metal into various parts, a few wax cross strappings and a wax rod ending with a funnel shape (sprue and runner) are also joined to the pattern at appropriate locations. The wax pattern or model of the icon,

with a gating system for metal flow, is now ready (Figure 1).

Mold making involves coating the wax pattern with layers of clay, known as investment—three layers for small icons and more layers for larger icons. A different clay is used for each layer. The first coat, about 3 mm thick, is made when fine loam or alluvial soil collected from the Cauvery river bed (called "vandal mann" in Tamil) is finely ground with charred paddy husk and mixed with cow dung, forming a thick mixture. This first coat performs two important functions: protection of the wax model and reproduction of the minute contours of the model. Thus, no portion of the wax model should be left uncovered except the wax sprue top surface, which is the outlet for the melted wax while dewaxing and the inlet for molten metal during casting. Further, no air bubbles should be allowed on the surface of this first coat, since they can spoil the mold cavity surface finish, and, in turn, that of the icon. During the clay-coating application, the wax model is kept on a piece of paper or cloth on the floor or a table, depending upon the size of the model, to avoid its deformation. The coating is applied to half the model, allowed to dry, and then the model is turned to coat the other half. It is crucial that the clay coating is dried either in mild sunlight or in the shade to prevent the wax model from melting.

The second coat or investment is made with a paste obtained by thoroughly mixing clay from paddy fields and sand, and combining that mixture with water in a 1:2 ratio. The thickness of this coat varies from 12.5–50 mm depending upon the size of the icon. The third coating is a paste containing a mix of coarse sand and clay. The mixture is applied after the second coating is dried. A fourth coat is applied only if necessary, based on the size of the icon. Especially with large icons, the mold must be reinforced with iron rods and wires to prevent the mold from giving way during handling and liquid metal pouring. When the last coat dries, one half of the mold is ready to withstand the pressure and heat of liquid metal. The same investment application procedure is repeated on the other half of the pattern, resulting in a completed mold with a wax model inside (Figure 3).

Next, the completed mold is heated in an open-ground oven using cow-dung cakes as fuel. The molten wax coming out through the runner is collected in a vessel containing water, and can be reused after any foreign matter is removed.

Silpasastras prescribe the composition of the alloy to be chosen for casting sacred icons. Archaeologists have excavated icons and idols proving that for the last 3,000 years, panchaloha (literally meaning an alloy of five metals) has been most widely used for making icons and idols. This five-metal combination of Cu, Au, Ag, Pb, and Zn was considered to be a highly auspicious composition and is still used for icons cast for worship. The important sources of information on making panchaloha are

recorded in ancient Sanskrit and regional literature, with artisans from South India perfecting the technology. Other compositions of panchaloha cited include Au, Cu, Ag, Pb, Fe, and Sn as well as the combination of Sn, Cu, Fe, Pb, and brass.[16] However, because of their high cost, gold and silver are no longer used in general-purpose icons. An alloy made by mixing copper, brass, and lead in the ratio 29:2:1 is commonly utilized for general-purpose icons. In some cases, tin is added in an amount equal to the lead content. Lead is added to make the alloy more malleable so that chiseling and engraving of the icon will be easy. The artisans believe that if the icon is made with copper alone, it will not have a lasting shine, whereas adding a little brass to copper results in a lasting shine and a lower melting point. It may be noted that brass is added as a master alloy to introduce zinc. The artisans calculate the weight of the alloy required to occupy the mold at eight times the weight of the wax model. Melting is carried out in a coke/charcoal-fired furnace using either a commercially available clay graphite crucible or a crucible made of clay by the artisans. When the alloy is being melted, the hollow mold is heated to red hot to drive away air bubbles from the inside of the mold cavity as well as to prevent sudden cooling of the molten metal, which could lead to an uneven surface finish. Heating the mold also prevents the mold from exploding because of the high heat of the liquid metal.

Figure 4. Fettled castings of the child Krishna and a banyan tree leaf.

Figure 5. Finished icon of the child Krishna on a banyan tree leaf (Aal elai Krishnan in Tamil).

When the temperatures of the metal and the mold have reached the levels required by the artisan for casting, the red-hot mold is firmly placed or buried in the ground so that only the sprue portion protrudes out. A cloth-wound metal ring is placed on the sprue top to support the hot crucible containing molten metal as well as to prevent overflow of the metal as it is poured into the mold. Care is also exercised that the metal stream does not cover more than half of the sprue opening to allow displaced air to escape from the mold cavity. In order to prevent the entry of any impurities floating on the surface of the molten metal, a piece of knitted jute cloth is used to cover the mouth of the crucible while pouring. The filled mold is allowed to cool slowly,

which normally takes a day or more depending on the size of the icon. However, if immediate cooling is necessary, it can be doused with water after 2–3 hours of casting.

The breaking of the mold to remove the icon is of great significance to the craftsman, since it is not merely an object but a transcendental entity. The fettling of the casting or breaking of the mold is initiated only when the mold has sufficiently cooled. The mold portion holding the icon head is always broken first followed by remaining portions. The iron rods and wires used as reinforcements are separated and preserved for reuse. The clay sticking to the icon is scrapped and then the connecting rods used as support in complicated icons are removed by chiseling. The fettled castings of the child Krishna and a banyan tree leaf are shown in Figure 4. The contours and details of the original wax pattern are recaptured by smoothing the uneven surfaces and then by chiseling. The details of dress and ornaments as well as other final touches are engraved into the icon. The icon surface is smoothed by rubbing it with fine-grade emery paper, and then it is cleaned with tamarind and a soap-nut-water mix and scrubbed with a wire brush. Finally, the piece is brushed with polishing sand and water. The well-finished icon is shown in Figure 5 after the two individually cast parts have been riveted.

The icon of the child Krishna on a banyan tree leaf (Aal elai krishna in Tamil) was made by Swamimalai artisans. Generally, they use 80% copper, 20% brass, and 5% lead for general-purpose icons. However, for icons to be installed in temples for worship, panchaloha containing 50% Cu, 16% Au, 8% Ag, 10% brass, and 16% Pb is used.

MAKING VESSELS, LAMPS, AND BELLS AT MANNAR, KERALA

The process followed at Mannar for making vessels, lamps, and bells is similar to that followed in Swamimalai for icon making. However, in the Mannar process, one half of the mold is made first over which the required thickness of wax is deposited, then the other half of the mold is made covering the wax pattern. The important steps involved in making a vessel (urli in Malayalam language) are shown in Figures 6, 7, 8, 9, 10, 11, 12, and 13 and those for making a bell are depicted in Figures 14, 15, and 16. These craftsman still follow the old method of using broken earthenware pieces as reinforcement in making utensils and bells (Figure 11). Brass and bronze are used for making utensils, and bronze (Cu-20%Sn) alone is utilized for making bells.

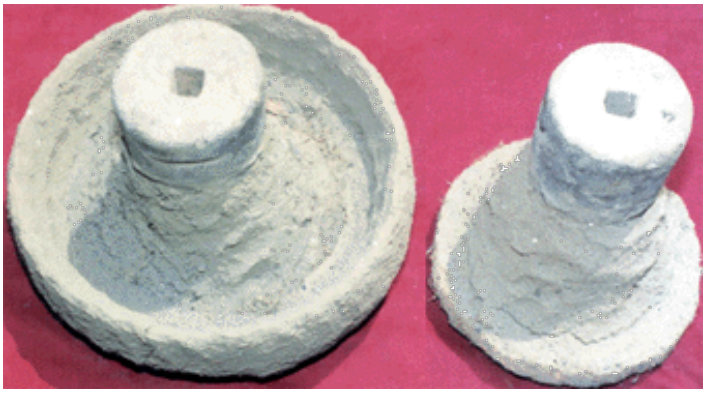

Figure 6. A portion of the mold built over the disc made out of a mixture of clay, wellground broken mold powder, and jute fiber.

Figure 7. Turning the mold using a sharp tool to make it concentric by rotating the same by hand.

Figure 8 (left). Applying a layer of fine powder mix followed by a wax layer is required to make the vessel thick enough.

Figure 9 (right). Turning excess wax from the mold portion.

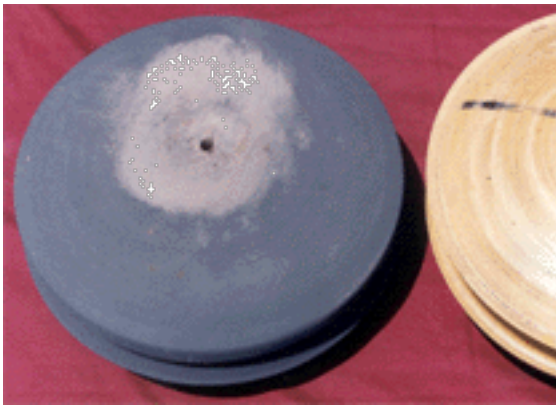

Figure 10. A mold portion with a fine powder mix layer and wax layer over it.

Figure 11: A finished mold for a vessel with broken earthenware pieces as reinforcements and the sprue for metal entry at the center.

Figure 12. The dewaxing of three utensil molds by heating them in coconut shells and collecting the molten wax in a vessel containing water.

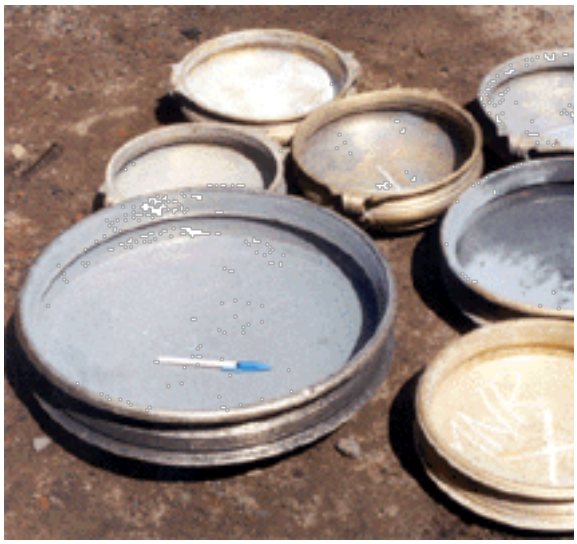

Figure 13. Finished vessels of different sizes and shapes.

Figure 14. Making one half of bell mold.

Figure 15. A bell mold with smoothed wax layer over which the other mold half is to be completed.

Figure 16. Fettled bells of two different sizes.

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